Introduction

The Navy is currently undergoing a drastic switch in the way it conducts operations as compared to the last twenty or more years. The fall of the former USSR and the increased threat posed by rogue nations has steered the Navy from concentrating most of its resources on the open "blue water navy" to a "brown water navy," more concerned with the littorals. This means that more research and a better understanding of near shore or coastal oceanography are needed. One of the important factors in understanding this is the Ekman Mass Transport, which could be a factor in near shore oceanography. Coastal upwelling/down welling is partially due to Ekman divergence or convergence in an area, which has military, scientific, and economic importance. Therefore, studying Ekman mass transport is a very valuable tool for a wide variety of organizations.

Ekman transport occurs, in the Northern Hemisphere, as wind blows over an open body of water. Due to the effects of friction caused by the wind stress i.e. drag coefficient and the Coriolis Force the surface currents flow 45 degrees to the right of the surface winds. However, due to frictional loss with depth the total mass Ekman transport is 90 degrees from the true surface wind directions. The depth at which the affects of the Ekman transport are felt depend upon a variety of parameters, for example, the latitude and surface wind speeds effect the depth the Ekman Transport would seize to exist at.

$$D_E = \frac{7.6}{\sqrt{\sin|\varphi|}} U_{10}$$

Using table (1) and our own ship data we can estimate roughly that our Ekman Transport would probably stop being noticeable between depths of 40m-30m.

This is based upon the fact that our latitude for the entire cruise was between

Table (1)

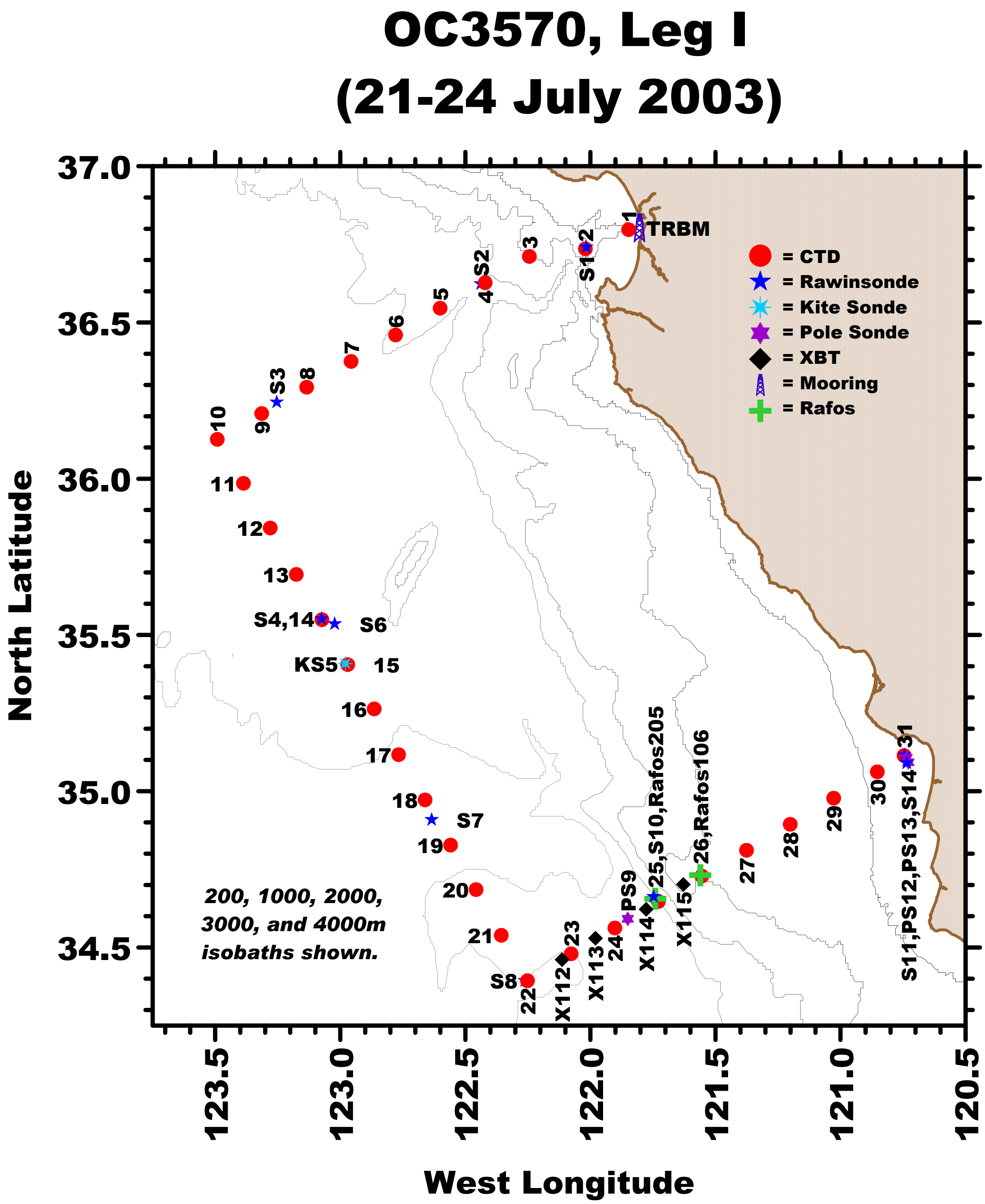
U_{10}(m/s)	Latitude	
	15°	45°
5	40m	30m
10	90m	50m
20	180m	110m

34 and 37 degrees North and our average wind speed was 7m/s. Therefore, using table (2) the deepest depth would be 90m and the shallowest would be 30m. However, the purpose of this study only concerned itself with finding the mass Ekman Transport in or out of the area analyzed during the OC3570 cruise. The purpose of calculating the mass Ekman Transport in or out of the box was to compare the number with the value computed for the geostrophic current in the same region. In an ideal world the two would match perfectly, but as the study showed, the oceans are not perfect and there are many factors and variables, which need to be examined in order to determine why the unbalance occurs.

Data Analysis

The cruise was conducted off the central Californian coast from 21st July to the 28th July 2003 on the Research Vessel Point Sur. The data used was collected off the ship's bridge equipment and then analyzed using the computer program MATLAB.

Fig(1)



Preliminary preparation of the data included isolating the relevant data and screening the bad values of data out of our analysis. Then the time and degrees latitude and longitude were converted into decimal format so that future calculations would be easier. Next each leg of the cruise was defined by its corner values of latitude and longitude. Once these initial “clean-up” procedures were carried out analysis of the wind data was able to take place.

The wind speeds for each leg were compared as an initial indication as to what the wind conditions were like during the cruise. It was obvious from these initial histograms that leg 2 clearly experienced much stronger winds than leg 2 or leg 1. To further analyze the wind conditions the wind speed vectors were plotted to give a good indication as to where the wind was predominantly coming from and at what speed. The general direction of the winds for the cruise’s portion of time was from the Northwest. Once the average wind was computed for each leg the wind stress could be determined using this formula:

Wind Stress(tau)(m/s)= wind speed .^2.*(1.2.*10E-3).*1.25

The wind stress vectors when plotted pretty much agreed with the average wind vectors, which is what is expected, since the wind stress is felt in the same direction as the wind. From here the Ekman mass transport could be computed from the mass transport equation:

Mass Transport=(((tau./(p*f)).*totaldist)./(1.0.*10E6))

Then ninety degrees were added to shift the transport to ninety degrees to the right, indicating what direction the current would move the water. Finally, to determine how this affected our particular area trigonometric adjustments were made to indicate how much of an effect the Eckmann transport actually had upon the movement of water in and out of our box.

Results

The final results yielded what seems to be an annual trend of Ekman mass transport out of the box. The two previous studies conducted on the 0C3570 cruise in 2001 and 2002 have very similar results as to what was found this summer. In 2001 the net mass Ekman transport was shown to be –0.17467 Sv (AhChuan, 2001) and Lora Egley in the summer of 2002 also computed it to be –0.2 Sv out of the box. The results from this year's cruise agree with this trend as the total mass Ekman transport was -0.1098 Sv. Yet, there was a positive flow of water being transported into the box from the first leg (-3.4236e-004 Sv), however this was counterbalanced by the outflow of leg 2 (-0.1067 Sv) and leg 3 (-0.0035 Sv). The slightly lower value found this year could be due to lighter winds experienced on this particular cruise, which would reduce the amount of mass transport. However, these results still may have some error associated with them simply due to the fact that the Ekman theory is based upon the assumptions that, a steady state exists, and it is a homogeneous ocean with no boundaries. Obviously, in this case we know this not to be true simply because of the close proximity to land, however these are the affects that need to be understood in order to better prepare for littoral missions.

Conclusions

The number produced for the mass Ekman transport seems to be acceptable knowing the two previous years' values. However, the geostrophic current was found to be, through a separate study on this cruise data, much bigger than the Eckman transport, which gives rise for concern since the two should equal in a perfect situation. This means that either the basic theories are wrong, errors occurred in the data calculation, or there existed other parameters, which were not accounted for. One possible reason for this non-correspondence of values could be due to a strong undercurrent, which is transporting large amounts of water into the box. This hypothesis was unable to be proved in this experiment because the instrumentation did not cover the entire water depth but only to 1000m. However, this phenomena seems like a plausible answer because knowing the bathymetry of the area, a strong, deep undercurrent would be possible. This scenario would account for the unbalanced currents because, as discussed earlier, the Eckman mass transport does not penetrate all the way through the water column so there would indeed be an imbalance caused by the "extra" undercurrent.

The whole scenario of the unbalanced water mass transport is an important question to understand both for the scientific community and the military. For the military in particular being able to predict and model what the environmental conditions will be for a certain area and time are crucial in mission planning. And for the scientific community one important aspect could be if upwelling is occurring how is that affecting the biologics in the particular region. Further studies need to be conducted to see what other factors could be contributing to this imbalance of forces, whether it is seasonal changes, bathymetry, or simply human error in calculations.

Recommendations

Advice for future studies on calculating the mass Ekman transport would be to calculate more accurate ways in finding an average wind speed, instead of purely just taking the mean wind speed along each leg. Also, a more accurate way to find when and where the data started being recorded so that every value is included. A more precise method of computing wind stress by including the weather conditions would yield perhaps more accurate results. However, the real problem comes in determining what part of the Ekman mass transport actually gets transported into or out of the box, though the method used in this experiment suffices, a better way could be found.

References

AhChuan, Ong, 2002: Geostrophic, Ekman and ADCP volume transports through CalCOFI lines 67,77 and line 77. OC3570, p1-17.

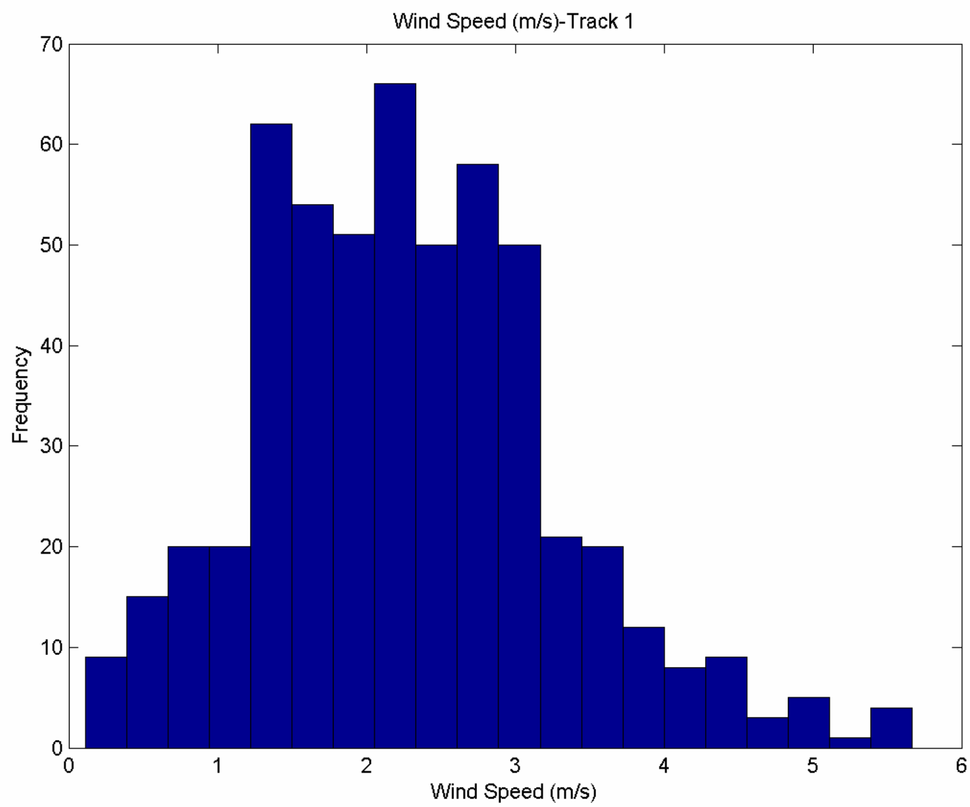
Egley, Lora, 2001: Wind stress and Ekman mass transports along CalCOFI lines: 67,70,77. OC3570, p1-16.

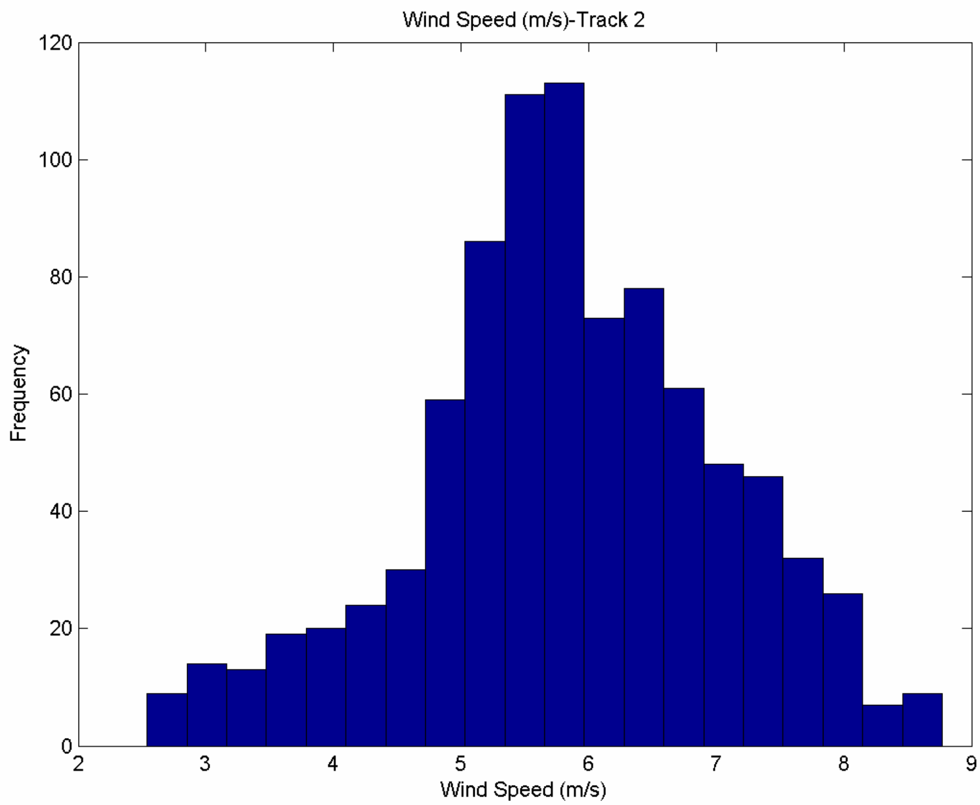
http://oceanworld.tamu.edu/resources/ocng_textbook/chapter09/chapter09_02.htm

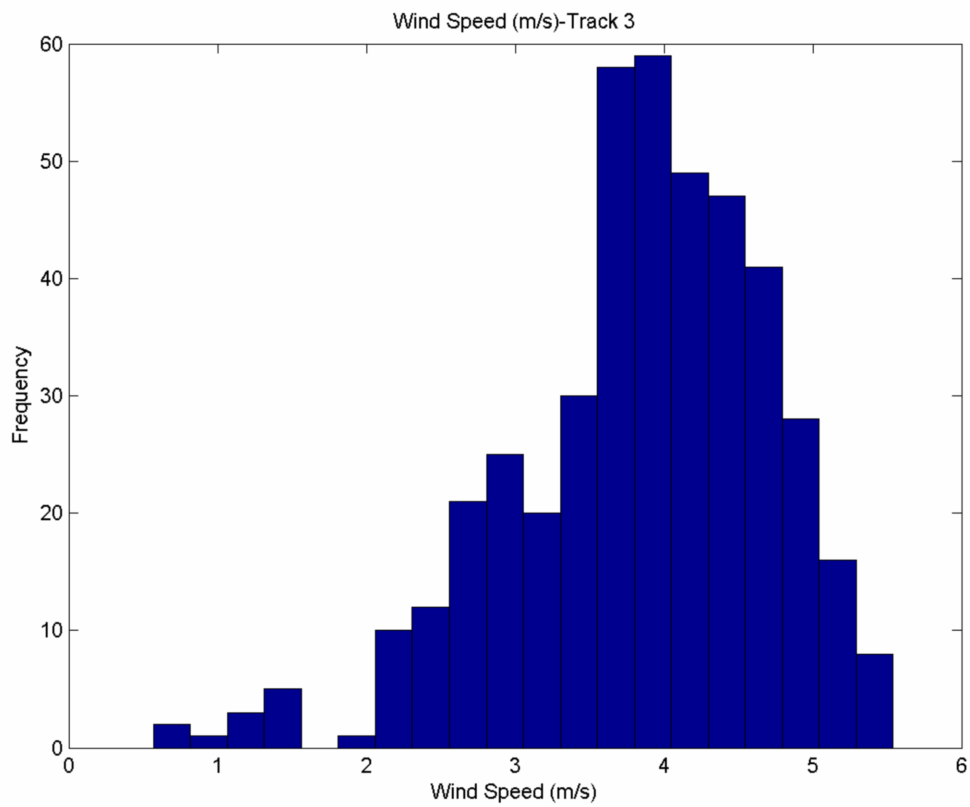
http://pub49.ezboard.com/feastcoastsurfforecastingrealmfrm1.showMessage?topicID=457.topic

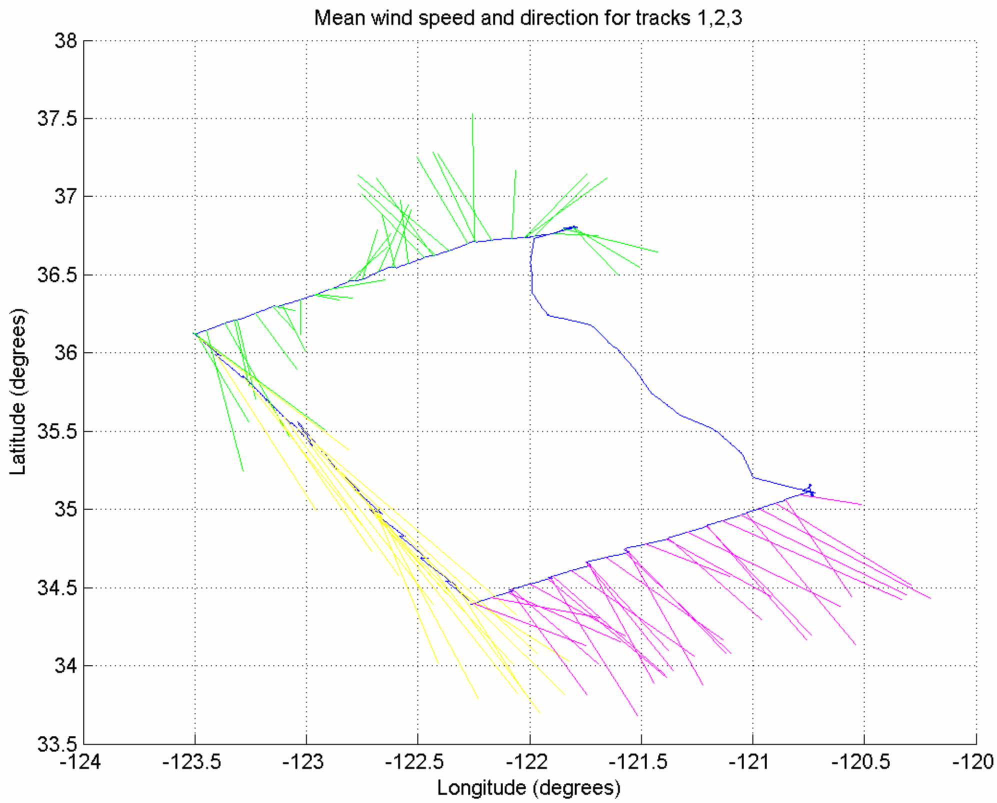
http://marine.rutgers.edu/dmcs/ms451/2002-Oct-21.htm

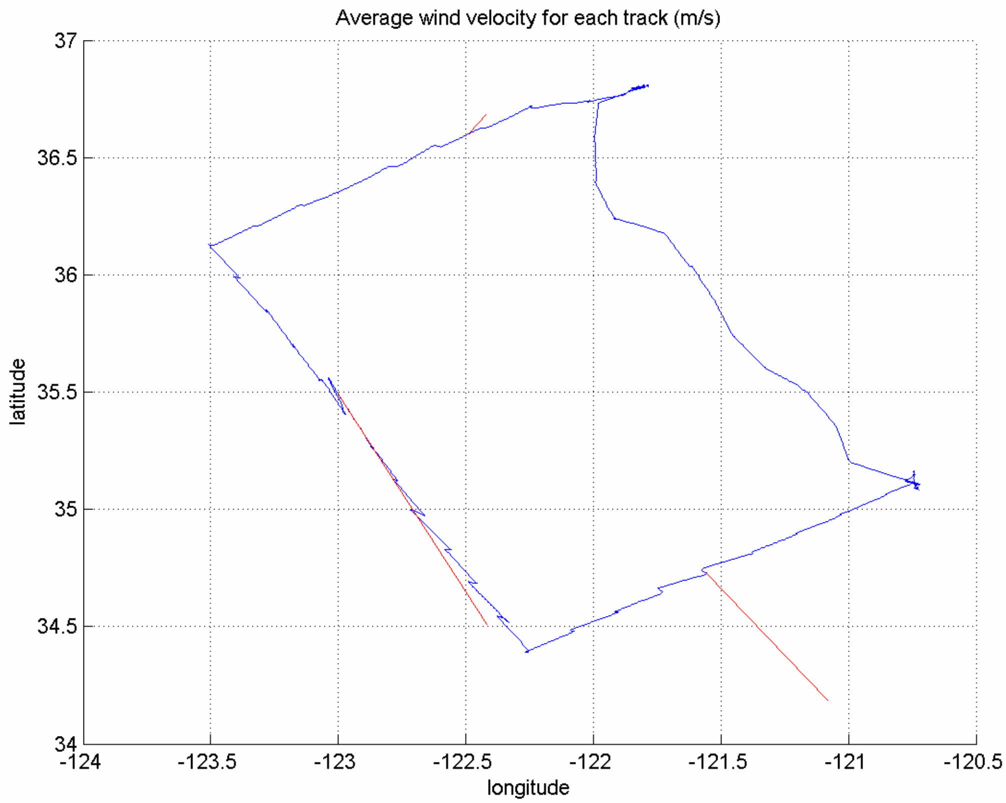
**** MATLAB functions received from Prof. Collins and Prof. Guest were used.

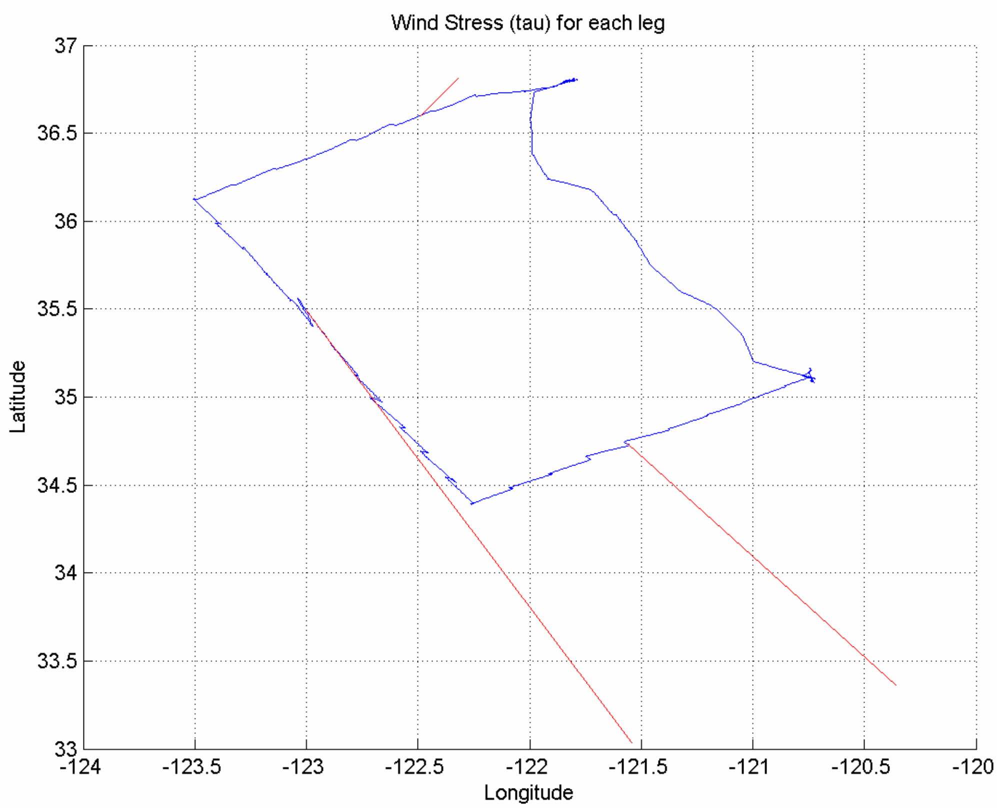

Wind Speed (m/s)-Track 1
Frequency
Wind Speed (m/s)
0
10
20
30
40
50
60
70
0
1
2
3
4
5
6


Wind Speed (m/s)-Track 2
Frequency
Wind Speed (m/s)
0
20
40
60
80
100
120
2
3
4
5
6
7
8
9

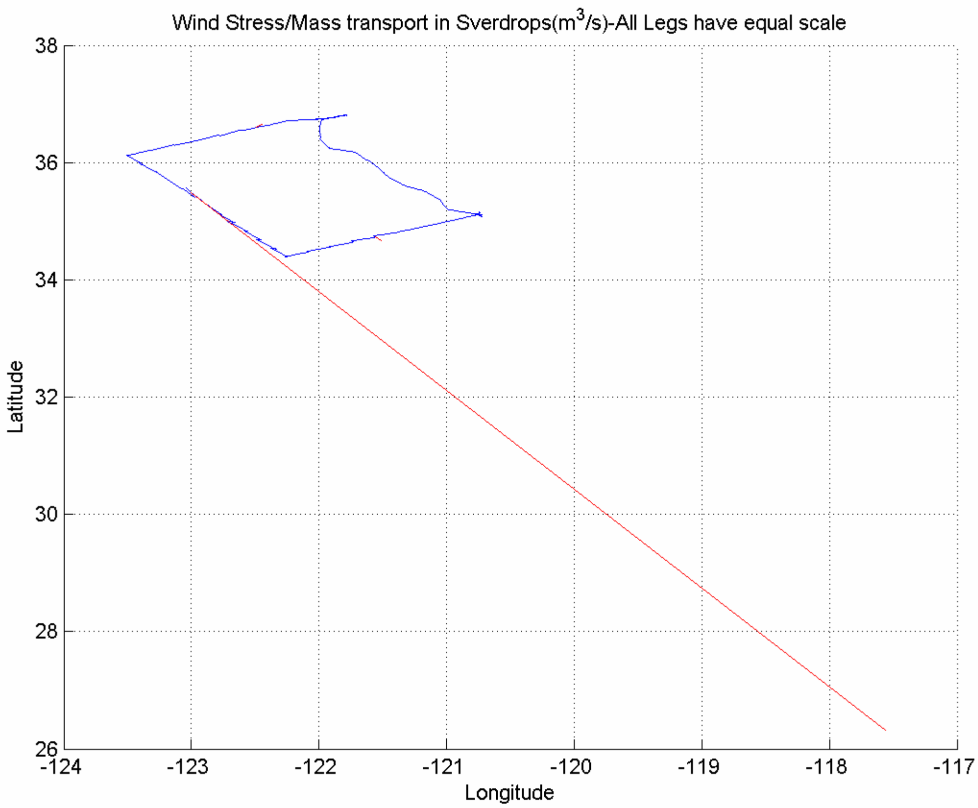

Wind Speed (m/s)-Track 3
Frequency
Wind Speed (m/s)
0
10
20
30
40
50
60
0
1
2
3
4
5
6

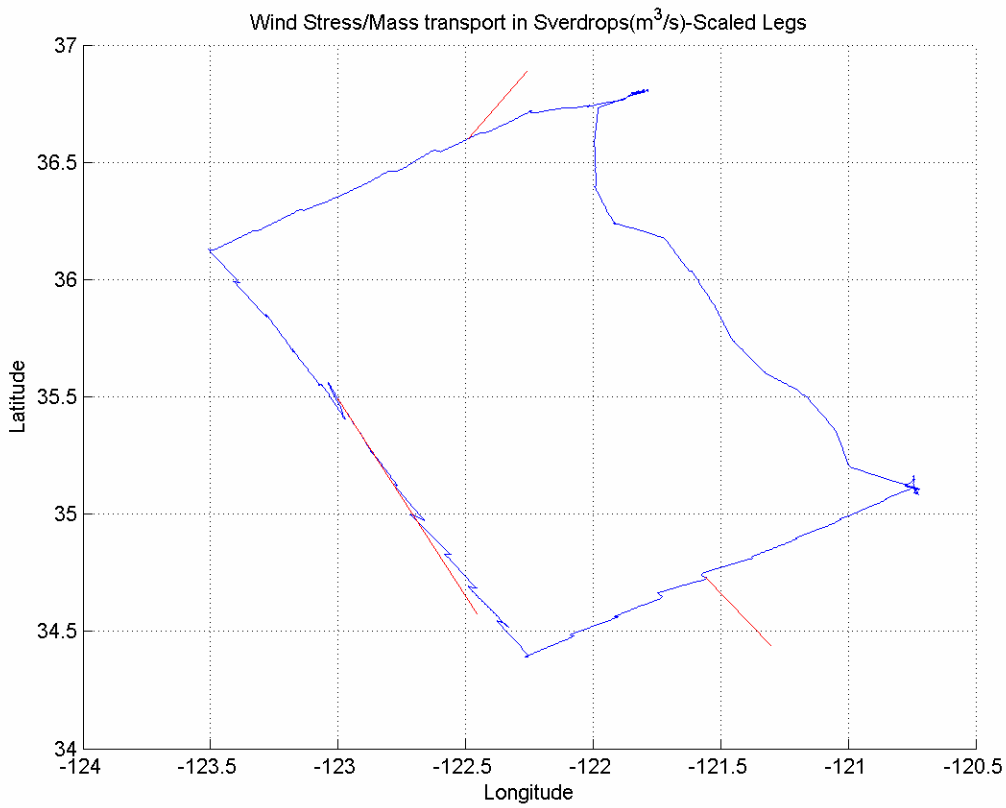

Mean wind speed and direction for tracks 1,2,3
38
37.5
37
36.5
36
35.5
35
34.5
34
33.5
-124
-123.5
-123
-122.5
-122
-121.5
-121
-120.5
-120
Longitude (degrees)
Latitude (degrees)


Average wind velocity for each track (m/s)
37
36.5
36
35.5
35
34.5
34
-124
-123.5
-123
-122.5
-122
-121.5
-121
-120.5
longitude
latitude



Wind Stress (tau) for each leg
37
36.5
36
35.5
35
34.5
34
33.5
33
-124
-123.5
-123
-122.5
-122
-121.5
-121
-120.5
-120
Latitude
Longitude


Wind Stress/Mass transport in Sverdrops(m3/s)-All Legs have equal scale
38
36
34
32
30
28
26
Latitude
-124
-123
-122
-121
-120
-119
-118
-117
Longitude



Wind Stress/Mass transport in Sverdrops(m^3/s)-Scaled Legs
37
36.5
36
35.5
35
34.5
34
-124
-123.5
-123
-122.5
-122
-121.5
-121
-120.5
Latitude
Longitude

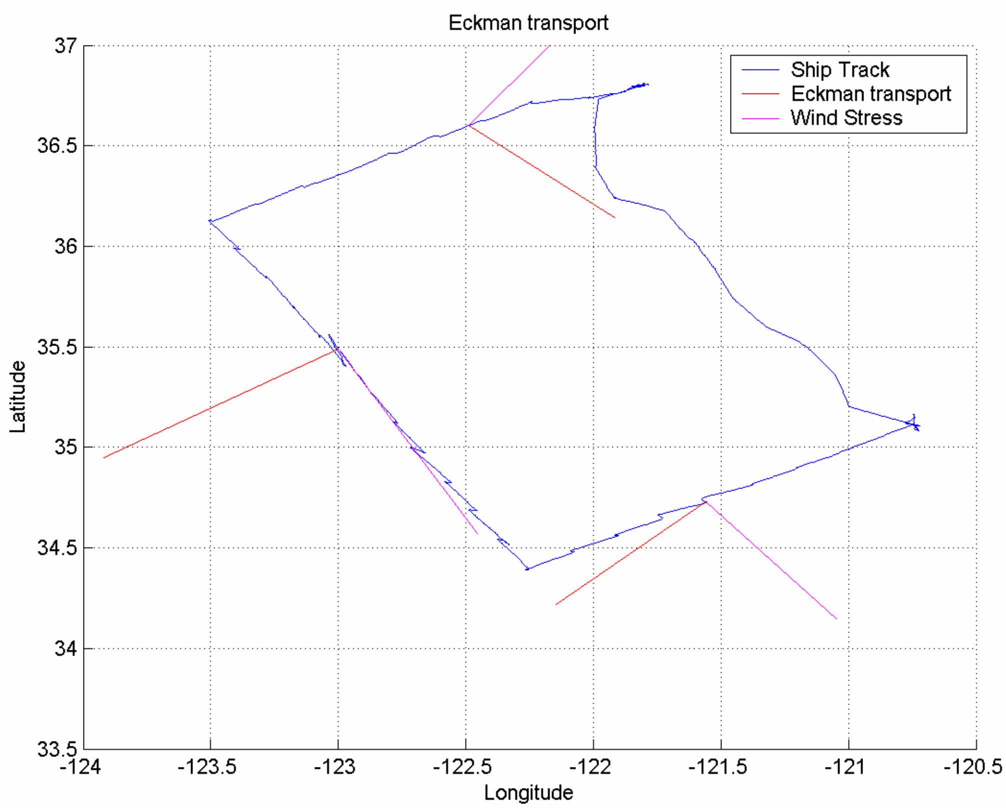

Eckman transport
Ship Track
Eckman transport
Wind Stress
37
36.5
36
35.5
35
34.5
34
33.5
-124
-123.5
-123
-122.5
-122
-121.5
-121
-120.5
Latitude
Longitude

Table (1)

U_{10}(m/s)	Latitude	
	15°	45°
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From: http://oceanworld.tamu.edu/resources/ocng_textbook/chapter09/chapter09_02.htm

Figure (1) Courtesy of Prof. Collins